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Local perceptions of environmental changes in fishing communities of southwest Madagascar

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ABSTRACT

Southwest Madagascar is a region that is significantly impacted upon by climate change. As in a lot of developing countries, the livelihoods of many communities in this region are dependent on fishing. This makes these communities particularly vulnerable to climate-related changes. We conducted a survey in two coastal fishing communities in the Toliara Province, Ambola and Ambotsibotsike. Using a free listing exercise, semi-structured interviews and focus group methods, we documented local perceptions of environmental changes and responses to changes. Results were compared, taking into account the differences in the degree of remoteness, market exposure and religiosity. Time periods that respondents reported as having had a high degree of change were compared to time periods of historical records of cyclones occurring in Toliara Province. Mostly, changes in the environment were said to have started 21–40 years ago. An overlap was observed between time periods when respondents observed changes in their environment and time periods of high magnitude cyclones. Answers relating to the local environment show that both villages identify with a sea culture, but the local ecological knowledge is arguably more accurate in the remote village of Ambola. In Ambotsibotsike God's intervention was predominantly identified as the source/cause of changes in the natural environment. Ambola also displayed a higher proportion of household members who participate in fishing from pirogues (at least one person per household). In both villages, the most reported change was a reduction of sea resources (64,2% of the answers in Ambola and 69.5% in Ambotsibotsike). Villagers' adaptation responses reflected the presence of NGOs in both villages. This influence was particularly strong in Ambola, where the establishment of reserves was found to be a predominant strategy to cope with change (54.8% of the answers). Our study provides additional insights that can be used in relation to the discussion of the role of the market, of religion, and the influence of NGOs on local knowledge. It seeks to contribute to the need to implement sustainable conservation strategies and successful community-based management plans.

1. Introduction

Coastal ecosystems play a fundamental role in maintaining coastal livelihoods in developing countries (Barbier et al., 2011; Costanza, 1999; Godfray et al., 2010). However, these ecosystems are endangered by ongoing climate and human-driven changes. Millions of people rely on coral reefs for their survival, but 19% of the world's coral reefs were lost in 2008 (Wilkinson, 2008). Under IPCC emission scenarios the global coral cover could decrease by 92% by 2100 (Speers et al., 2016). Increasing sea temperatures and negative impacts associated with the encroachment of human activities are threatening coral reefs globally (Hughes et al., 2003). This is likely to cause serious difficulties for social and ecological systems trying to adapt to these rapidly occurring changes (Berkes et al., 2008; Cinner et al., 2012; Fernández-Llamazares et al., 2015). The South-West Indian Ocean is warming relatively faster than others (Hobday and Pecl, 2014). This phenomenon is having an influence on the distribution and abundance of marine species (Cochrane et al., 2009). Increased ocean temperatures have both terrestrial and coastal implications. For instance, decreasing rainfall phenomena occur in some areas affecting culture-based livelihoods (Funk et al., 2008). High rainfall episodes can also be triggered by the ENSO phenomenon. For instance the 1998 ENSO induced a massive coral

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bleaching in the Western Indian Ocean (McClanahan, 2008). This episode resulted in 30% coral mortality regionally (Wilkinson, 2008). These regional phenomena could well be causing a decline in fish production and consequently increasing the vulnerability of millions of people (Cinner et al., 2012).

Madagascar is one of 110 countries worldwide that are particularly vulnerable to coral reefs disappearing, as it relies heavily upon reefs both economically and socially (Burke et al., 2011). The country has recently been named a dark spot in a review of global reef health (Cinner et al., 2016). The socio-economic conditions of traditional coastal fishing communities in Madagascar are characteristic of tropical coastal poverty: a high birth rate, child labour, poor access to health services and potable water, isolation from markets and schooling, fisheries-dependant livelihoods, and the vulnerability of ecosystems that communities rely on (Billé and Mermet, 2002; Cripps, 2009). In 2003, over half of the Malagasy population was living within 100 km of the coast, and 10% within 30 km of reefs (Burke et al., 2011). In this context, marine resources are of critical importance for many coastal communities (Le Manach et al., 2012) ensuring food security for many of them. With 4.7 million tons of fish caught during the 1950–2008 period (Le Manach et al., 2012), Madagascar's food security is widely reliant on fisheries, especially small scale fisheries. Climate change is likely to increase human vulnerability in this region, especially as Madagascar is located in a very active cyclonic area and the increased sea surface temperature has amplified the frequency and intensity of these meteorological events over the past 50 years (Emanuel, 2005; Webster et al., 2005). In South-West Madagascar, the social and economic vulnerability is even higher as the region's ocean is warming even faster than other areas of the country (Hobday and Pecl, 2014). Further, fisheries are the primary source of sustenance as well as being the primary source of income for people in that region (Laroche et al., 1997). Livelihood diversification remains limited and most coastal communities are likely to over-exploit their resources as a poverty coping strategy (Harris, 2011). This diminishes ecosystem and livelihood resilience and increases vulnerability to ongoing global changes (Cinner et al., 2012).

Despite substantial epistemological and contextual differences between indigenous and scientific knowledge (Agrawal, 1995), they can be complementary. Indeed, the contribution of local people's knowledge to successful development (e.g. Berkes et al., 2000; Brokensha et al., 1980; Gadgil et al., 1993) and climate change adaptation plans (e.g., Grothmann and Patt, 2005) has been shown. In the absence of scientific studies, local knowledge can contribute to building a knowledge baseline, being more likely to capture environmental signals, extreme events, compared to scientific knowledge which is synchronic (Moller et al., 2004). In some instances, local knowledge allows to better identify the characteristic of ongoing changes because local people can observe changes longitudinally and in some instances at very fine scales (Aswani et al., 2015; McCarter and Gavin, 2014). Documenting local knowledge to hybridize with existing scientific knowledge is a good start to formulate locally contextualized plans to cope and/or adapt to change (Carpenter and Gunderson, 2001). Local and indigenous traditional knowledge are also of significant importance in the planning and the management of conservation areas. Local knowledge integration in local planning, through the promotion of participative approaches or the implementation of locally-managed systems, has proven to be effective (Berkes et al., 2000; DeWalt, 1994; Gadgil et al., 1993). It follows that documenting local perceptions is important for identifying local adaptation strategies, and for designing anticipatory adaptive response plans. This process also provides the opportunity to compare local knowledge to scientific data (Aswani et al., 2015; Chaudhary and Bawa, 2011) in order to test and validate scientific hypotheses (Chaudhary and Bawa, 2011).

In Madagascar, where dependence on marine resources is high and scientific research is incomplete or patchy, it is crucial to document indigenous traditional knowledge in order to build a knowledge baseline. Within south-west Malagasy fishing communities, the potential is important in terms of ecological knowledge as those areas have remained relatively undisturbed by the influence of markets and mass tourism. While the fishing effort of artisanal fisheries has reportedly increased over the last decade (Le Manach et al., 2012), the region has at the same time been influenced by many extreme meteorological events (i.e. cyclones, floods, droughts, etc). In this study, we document indigenous perceptions of environmental change and the drivers to which they are related in two communities of the Toliara province in South-West Madagascar. The aim of this study is to assess the local perceptions of environmental feedback loops, the way people discriminate natural from anthropogenic causes in the processes they observe, and to gauge their responses to the described changes in the environment, i.e. their adaption mechanisms. More generally, we wanted to evaluate how local perceptions of environmental and climatic change could be integrated into regional and national climate change adaptation plans for coping with the effects of ongoing profuse environmental and climatic transformation in this large island nation.

2. Methods

2.1. Study sites

The SW coastal region of Madagascar is mainly populated by the Vezo ethnic group ("people of the sea"). They inhabit the coastal belt from Androka, in the south, to Morondava in the north of southwest Madagascar. In 2009, 35% of the coastal population was distributed along 350 km of coastline and was primarily engaged in artisanal fisheries (Bemiasa, 2009). The region has been characterized by migration flows from inland people who are locally considered as "hunter-gatherer" and "pastoralist" ethnicities searching for other sources of income. This is believed to have contributed to the reduction of stocks in the case of sea cucumber fisheries (McVean et al., 2005). In the region, authors highlight that reef species are dominant in local catches (Laroche and Ramananarivo, 1995). It follows that human pressure on reefs is likely to have dramatic consequences for peoples' livelihoods in this region.

Numerous NGOs are active in the region, contributing to local development and sustainable use of resources by implementing new MPAs and other resource management initiatives. For instance, in Ambola, the WWF has been active since 2008, developing community tourism and encouraging sustainable foraging techniques. Octopus fisheries (*Octopus cyanea*) are the most prevalent form of fishery along the southeast coast and the region also supports Madagascar's largest traditional fishery (Laroche and Ramananarivo, 1995; Laroche et al., 1997). Octopus fisheries are critical for many coastal communities, and the WWF and Blue Ventures have been taking action in the region for more than a decade to initiate locally-managed octopus reserves based on sustainable fishing strategies. This has resulted in an increase in the number of octopuses caught between 1996 and 2004 (L 'haridon, 2006).

Two study sites were chosen in the area of interest (South-West Madagascar) in association with the Fisheries and Marine Sciences Institute (IH.SM), Madagascar, and WWF Madagascar. The selection was made based on our IH.SM counterparts having contacts in both villages to facilitate participation. And on villagers' livelihoods mainly relying on natural resources. We considered two communities of similar size, with a subsistence economy relying on artisanal fish catches, but with different levels of economic diversification and market integration. Ambola, located 80 km south of Toliara is made up of about a hundred households, relying mainly on fisheries. The village is accessible within 3.5 h drive from Toliara through taking a ferry in Saint-Augustin to cross the Onilahy River. The NGO WWF has been working in the village for the past 10 years teaching sustainable fishing techniques for octopus fisheries and trying to implement an eco-tourism economy. Ambotsibotsike is located 12 km North of Toliara, is made up of about 120 households, and relies on mangrove and marine fisheries.

The village is accessible within half an hour drive from Toliara and is close to the popular tourism centre of Ifaty. In contrast to Ambola, which is remote, Ambotsibotsike is quite accessible, literally set along a national road. This village is less reliant on the sea as there are other economic options in the vicinity.

2.2. Materials and methods

A total of 48 surveys were administered over the sampling period (Ambola n = 25, Ambotsibotsike n = 23). The unit of analysis was at the household level and a systematic sampling technique was applied, as village organizations did not possess knowledge of the number of households in either of the communities. Transects were drawn through a map of the two villages, after which every second house on each transect was sampled. Questionnaires were aimed at the head of the household, as identified by the household members themselves, and if unavailable, any household member with knowledge of the household. The two villages were sampled according to the same method (i.e., systematic sampling). The interviews were conducted in Malagasy through translators. Each interview consisted of 15 questions about the respondent and their household's livelihood characteristics, a free-listing exercise (appendix C) to identify the various ecological unit dimensions recognized by the villagers, and open questions about the changes observed in their environment over the last decades. We use "ecological unit dimension" as a term to refer to each subsection of the environment, as identified and classified by locals (e.g. lagoon, barrier reef and fore reef could be examples of environmental dimensions for the environment "sea"). Ecological unit dimensions may vary in their scale and terminology depending on the particular respondent and his/her locality.

In addition, a participatory mapping exercise was carried out in parallel to the questionnaire activity. Focus groups were constituted of elders and experienced fisher folk were picked using an opportunistic and rapid snowball method for the purpose of documenting and mapping the environmental characteristics (i.e., the different ecological unit dimensions and their vernacular names) and perceived changes over the past decades. Desktop data collection of GIS data at relevant spatial scales took place in association with The Fisheries and Marine Sciences Institute, Toliara, Madagascar (IH.SM) and the National Oceanography Centre, Southampton, UK. Data that were sourced prior to the fieldwork included satellite images (Google, DigitalGlobe), country boundary and infrastructure data (Defense Mapping Agency, 1992). The data were compiled using Manifold GIS software (www.manifold.net), and hard-copy charts were printed out in A1 format and laminated for use in the field. During the participatory GIS exercise, a GARMIN GPS12 was used and all data were incorporated into the Manifold GIS. Spatial information was collected on environmental characteristics (ecological units and local names) as well as patterns of use and perceptions of change over time.

The first step consisted of reconciling all the dimensions cited by the respondents in order to elaborate generic environment categories. Data were reported in a database and codified in order to harmonize between both villages. As environmental data were scarce in the region and in order to assess the co-occurrence of the changes reported and historical meteorological events, we made use of historical data on cyclones from the Southern Hemisphere Tropical Cyclone Data portal of the Australian Bureau of Meteorology (www.bom.gov.au). The cyclone events were selected according to whether or not their trajectories met the studied region using a 100 km buffer around Toliara and the selected events were listed in a table (Table A.1). Household interview outcomes were also compared in order to assess if a consensus existed. A Pearson's Chi-squared Test was done to determine whether the distribution of answers differ across the two sampled communities. Elsewhere, data was analysed using descriptive statistics. Schemes were drawn to illustrate the responses of villagers to the environmental changes for the most quoted change.

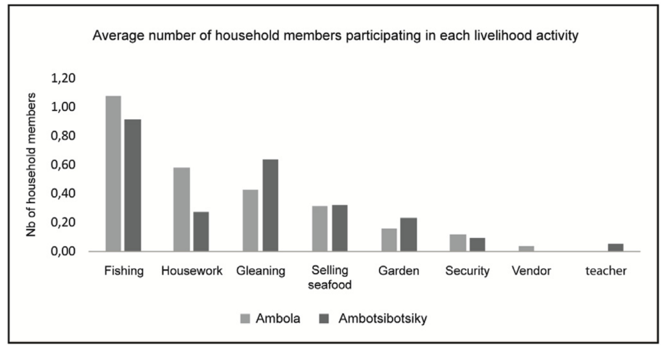

Fig. 1. Average number of household members participating in each livelihood activity per community for Ambola (n = 26) and Ambotsibotsike (n = 22).

3. Results

In Ambola we interviewed 19 males and 6 females, giving us 123 answers, of which 104 answers reported a change in the marine environment of Ambola. In Ambotsibotsike, we interviewed 14 males and 9 females, giving us 108 answers, of which 85 answers reporting a change (Table B1.). In Ambola, 50% of the respondents were mature males (+50 years old) and in Ambotsibotsike, 34.8% of the respondents were mature males.

A total of seven livelihood activities were listed by household members as being participated in across both communities. Pearson's Chi-square test revealed that the livelihood activities that community members participated in are independent of the community the activities occur in ($\chi 2 = 6.21$, $p > 0.5$). The combination of fishing and gleaning represented the highest importance to livelihood activities in both communities, both in terms of the number of household members engaged (Fig. 1), as well as the amount of time spent on these fishery related activities. An additional activity related to fisheries, namely the selling of seafood, also contributed considerably to the active engagement of household members and their time spent on livelihood activities. Under the 'housework' category of livelihood activities and unsurprising for a semi-arid region, only 12% of the households interviewed in Ambola had a plantation area dedicated to the cultivation of crops. In Ambotsibotsike, t 23% of households had a plantation. Concerning animal husbandry, 77% of households in Ambola owned livestock, whereas 64% of households in Ambotsibotsike farmed with animals. Livestock in Ambola primarily consisted of smaller animals such as ducks, chickens and goats, while in Ambotsibotsike livestock also comprised chickens, as well as larger animals like pigs and cattle (locally known as *zebu*).

A total of 28 vernacular names were given to qualify 7 different dimensions by Ambola respondents. *Anaovany*, meaning the lagoon area, was the most cited environment in Ambola (quoted by 76% of respondents). In Ambotsibotsike, 33 vernacular names were given to qualify 5 main dimensions, showing a lower consensus and a lower environment complexity than in Ambola. *Saha*, a word meaning "garden" in Malagasy and used to describe the mangrove ecosystem in this village, was the most quoted environment (91% of respondents). For the participatory mapping focus groups, these were made up of 8 participants in Ambola and 20 participants in Ambotsibotsike. In Ambola, they identified 12 dimensions (Fig. 2a) of which half were referring to the reef environment, whereas 8 dimensions were quoted in Ambotsibotsike (Fig. 2b), with a lower degree of detail.

Respondents identified 1.8 dimensions composing the marine environment in Ambotsibotsike and 2.7 in Ambola, which could indicate the existence of a greater knowledge of the sea in Ambola as well as the possibility that it could reflect a higher ecological/ecosystem diversity. The average number of environments quoted by respondents was higher in Ambola (4.1) than in Ambotsibotsike (3.8) but the standard

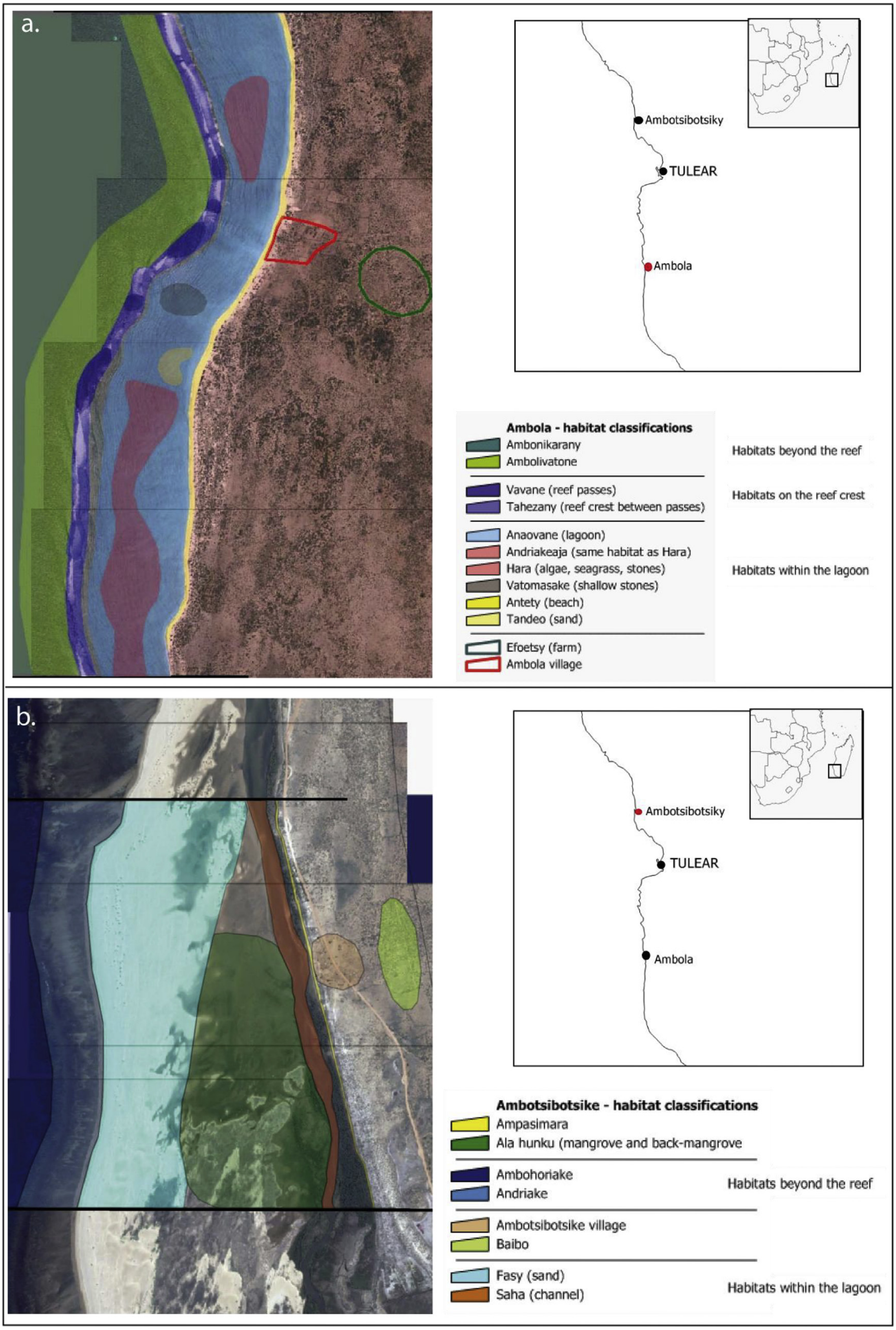

Fig. 2. Indigenous mapping of local environment in Ambola (a) and Ambotsibotsike (b).

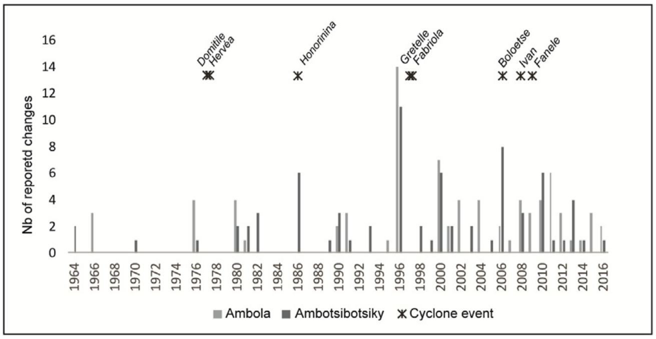

Fig. 3. Years associated with change occurrence for Ambola (n = 104) and Ambotsibotsike (n = 85).

deviation shows a weaker homogeneity in the answers in Ambola. On the one hand, this result can be explained by the existence of a richer knowledge shown by a wider diversity of environments quoted, and in the other hand, by the fact that knowledge is held by a specific category of villagers i.e. mature people and elders. In Ambotsibotsike, the lower score could be interpreted as the existence of poorer environmental knowledge. For instance, whereas the vernacular name *saha* is supposed to designate the mangrove channel, respondents would use it when referring to the mangrove ecosystem as a whole (trees + channels).

The interview data showed a total cumulated number of changes reported at 104 for Ambola against 85 for Ambotsibotsike, which averages as 4.1 environmental changes quoted per respondent in Ambola and 3.8 quotes per respondent in Ambotsibotsike (Table B1.). Chi-square tests showed that respondents in both villages tended to report the changes to occur in the same types of environments ($\chi2 = 59.4$, $p < 0.001$) e.g. reefs and fore-reefs areas. Although respondents in Ambotsibotsike reported more changes occurring in the mangrove ecosystem (39%), either the mangrove forest or the channel where villagers harvest shrimps and crabs. The most reported change was a decrease in sea resources, whether in marine or mangrove environments. All of the Ambotsibotsike village respondents said they noticed a decrease of resources, an observation which was echoed by 23 of 24 respondents in Ambola ($\chi2 = 24.4$, $p < 0.001$). In that village, the majority of respondents (58%) reported they were observing a decrease of marine resources, namely for octopus and fish.

Many respondents reported changes started 20 years ago (Fig. 3). Indeed, for each village, approximately 15% of the answers gathered about changes in the environment were said to begin in 1996 despite no notable event occurring this year. Nevertheless, the period 1996–1997 cyclone season has been deleterious as reported by Le Goff (Le Goff, 1998), made up of a succession of cyclones striking the southwest region i.e. the succession of *Fabriola* (2nd to 9th of January 1997) a tropical storm and *Gretelle* (19-31 January 1997) a category 4 tropical cyclone that resulted in much damage, 152 deaths and 80 000 homeless Malagasy people was reported by an article of the 6th February 1997, in the Daily News. The notable quotation of the year 1977 coincides with the occurrence of 2 cyclones which affected the Toliara region; the tropical storms *Domitile* in January and *Hervéa* in February (Table A1.). Ambotsibotsike respondents quoted the year 1986 frequently, which could correspond to the striking of *Honorinina*, an intense tropical cyclone which trajectory, north of Toliara, might have more directly impacted the village. Similarly, the year 2006 was recurrent in Ambotsibotsikan quotes. The same year, the tropical cyclone *Beloetse* struck in January 2006 with a trajectory impacting the Toliara area. The year 2000 was widely quoted by Ambolan respondents, however it matches no large scale meteorological event. The year 2010 was generously quoted in both villages. Two cyclones were recorded the same year in the vicinity, but one might rather consider the two intense tropical cyclones, *Ivan* and *Fanele*, which respectively affected the area in February 2008 and January 2009. In 2008, Ivan crossed 6 regions and

Table 1
The three most quoted changes for each dimension and in each village for the cumulated answers, with *n* the number of quotes, and *ts* the total score for that category.

	Change 1		Change 2		Change 3	
	Ambola	*Ambotsibotsiky*	*Ambola*	*Ambotsibotsiky*	*Ambola*	*Ambotsibotsiky*
Beach	Cleaner (n = 8, ts = 12)		Erosion (n = 3, ts = 12)		Dirty (n = 1, ts = 12)	
Dunes/Sand	Height diminution (n = 3, ts = 5)	Sand migration (n = 4, ts = 4)	No change (n = 2, ts = 5)			
Fore-reef	Less fish (n = 13, ts = 20)	Less fish (n = 8, ts = 12)	More corals and fish (n = 3, ts = 20)	No change (n = 2, ts = 12)	Algae cover decrease (n = 2, ts = 20)	Damaged reefs/Don't know (n = 1, ts = 12)
Land	No change (n = 8, ts = 19)	No change (n = 14, ts = 20)	Deforestation (n = 7, ts = 19)	Deforestation (n = 4, ts = 20)	cleaner (n = 3, ts = 19)	Draught (n = 2, ts = 20)
Mangrove		Less fish and shrimps (n = 22, ts = 40)		Sedimentation (n = 8, ts = 40)		Size decrease/less trees (n = 4, ts = 40)
Pelagic	Less fish (n = 10, ts = 24)	Less fish (n = 5, ts = 9)	No change (n = 6, ts = 24)	Size decrease/sedimentation/No change/Don't know (n = 1, ts = 9)	Fish size decrease (n = 4, ts = 24)	
Reefs	Less fish and octopus (n = 27, ts = 42)	Less urchins and octopus (n = 16, ts = 23)	Damaged reefs (n = 8, ts = 42)	No change (n = 3, ts = 23)	Fish size decrease (n = 3, ts = 42)	Damaged reefs (n = 2, ts = 23)

Table 2
Reported effects induced according to the changes, expressed in % of answers.

		Impact ecosystem negatively	Impact livelihoods negatively	Improve livelihoods	No effect	Don't know
Less sea product	Ambola (n = 50)	10	88	0	0,0	2
	Ambotsi. (n = 51)	0	90,2	0,0	9,8	0
Benthic changes	Ambola (n = 10)	60	20	0	20	0
	Ambotsi. (n = 2)	100	0	0	0	0
More products	Ambola (n = 7)	14,3	0	42,9	42,9	0
	Ambotsi. (n = 1)	0	0	100	0	0
Size decrease	Ambola (n = 8)	25	75	0	0	0
	Ambotsi. (n = 7)	0	85,7	0	14,3	0
Sedimentation process/geomorphologic changes	Ambola (n = 4)	50	25	0	25	0
	Ambotsi (n = 10)	80	20	0	0	0
Deforestation	Ambola (NA)	NA	NA	NA	NA	NA
	Ambotsi. (n = 4)	75	25	0	0	0

caused 22 deaths in Madagascar (https://www.unicef.org/french/emergencies/madagascar_42931.html) followed by *Fanele* which affected 25,000 people the following year (https://www.unicef.org/emergencies/madagascar_47583.html).

The top 3 answers given by the respondents about the changes observed were compiled in a table (Table 1) for each environment. For the environments they have in common, respondents of both villages reported the same trends.

The Ambola focus group reported a change of some fish species distribution patterns, with a net lowered presence in the lagoon area (reef dimension). This assessment was also made by household respondents, and often interpreted as migration phenomena by both categories of participants. In Ambotsibotsike, the reef-burying phenomena induced by the spit's sand migration was identified by both groups of respondents and was said to begin from the early 2000s by the focus group. Similarly, a decrease of prawns and the mangrove deforestation were unanimously observed in the mangrove channel.

When asked if the changes quoted resulted in a problem or an opportunity, both villages responded differently ($\chi2 = 7.35$, $p > 0.1$). Respondents mostly claimed (89.1%) that the decrease in catches was impacting their livelihood in terms of food security and in terms of economy (Table 2). Similarly, the decrease of the capture size was said to be a problem impacting livelihoods (81.3% of answers). In Ambotsibotsike a portion of the respondents (respectively 9.8 and 14.3%) said that those changes in amount and size of products had no effect on their life nor the environment. A deteriorated reef, referred to as "benthic changes" in Table 2 was said to be a problem at the ecosystem level, rather than for livelihoods. The same assessment was made for geomorphologic processes category (sand migration, beach erosion, etc.) since half of respondents said the change had repercussions for the ecosystem.

When looking at the change the most cited by the respondents of both villages, i.e. a decrease in sea/mangrove resources, most of Ambola's respondents (70.4%) identified the increase of human pressure, i.e., more fishers, more inhabitants, and of their use of resources as being at the origin of this change (Fig. 4). In Ambola, most of them (54.8%) said they were making reserves to cope with these perturbations, whereas most of Ambotsibotsike villagers (18.1%) said they were adapting foraging techniques and strategies, like for instance, improving gears or fishing further off-shore (Fig. 5). In contrast to Ambola, villagers identified nature-driven causes as mostly being at the origin of these decreases. Because of its particular configuration, i.e., settled along a mangrove ecosystem enhanced by the presence of a dynamic sand spit, Ambotsibotsike villagers reported more changes of geomorphological nature (16.5% of reported changes, against 4.8% for Ambola), namely ongoing mangrove and lagoon sedimentation processes. This environmental change appeared to be obvious to most villagers, hence explaining why so many of them mentioned nature-driven origins to changes occurring in Ambotsibotsike. As an adaptation strategy, a small proportion of respondents in Ambola (7.1%) reported they were resorting to prayers. Finally, 41.8% of Ambola respondents and 37% of Ambotsibotsike respondents said there was "nothing to do" to cope with change (Figs. 4 and 5).

4. Discussion

The assessment of perceptions of change provides useful insight into the local understandings of vulnerability and resilience. Communities can reveal their own understandings of ecological systems and the way they comprehend positive or negative environmental feedback loops in terms of how these relate to their livelihoods and communities. Respondents were asked to provide estimates of the period over which changes occurred. This provided a temporal dimension that generally goes beyond available scientific data. Adaptation processes were also interrogated by asking respondents about the way they were adapting to environmental perturbations. This allows for insights into vulnerability and resilience. The most important changes observed by the focus group were consistent with individual answers for both villages. In Ambola, the changes mostly related to the decrease in sea products and to sedimentation process in the mangrove and the reefs in Ambotsibotsike. We found similarities between the responses about changes, in terms of when these occurred, and the historical high magnitude cyclonic events. Taylor et al. (Grech et al., 2012) showed that salient weather-related events were proven to contribute to people's belief about climate change, explaining why certain dates are more memorable than others. In Ambotsibotsike, the highly quoted year of 1986 corresponds to the time of establishment of the Ambotsibotsike village. According to the village chief, the community was created by some Belitsake villagers after "a huge cyclone", probably *Honorinina*, caused tremendous damage and modified the landscape permanently. Following this event, many villagers moved northward to make a new settlement. The cyclone *Boloetse* and its associated high wave energy which hit the area in 2006 are reported to have contributed to coral loss in the area (Andréfouët et al., 2013). A deterioration of the coral reef substrate is likely to indirectly impact fishing activities. This could also explain why the human origin wasn't reported as being the main cause of the changes observed in the mangrove.

Answers about the different dimensions composing the local environment reflected the importance of the reef ecosystem for the Ambola population, and of the mangrove ecosystem in the case of the Ambotsibotsike. Even if respondents from both villages identified with a sea culture, which is prevalent among Vezo people of SW Madagascar, Ambola villagers arguably possess a more accurate knowledge since they identified more marine environments than Ambotsibotsike villagers (2.7 vs. 1.8 dimensions per respondent). The fact that Ambola is an older settlement than Ambotsibotsike, and with a closer proximity to the sea could account for this observation. The Ambotsibotsike village was reported to date from 1986 by the village president. Following a

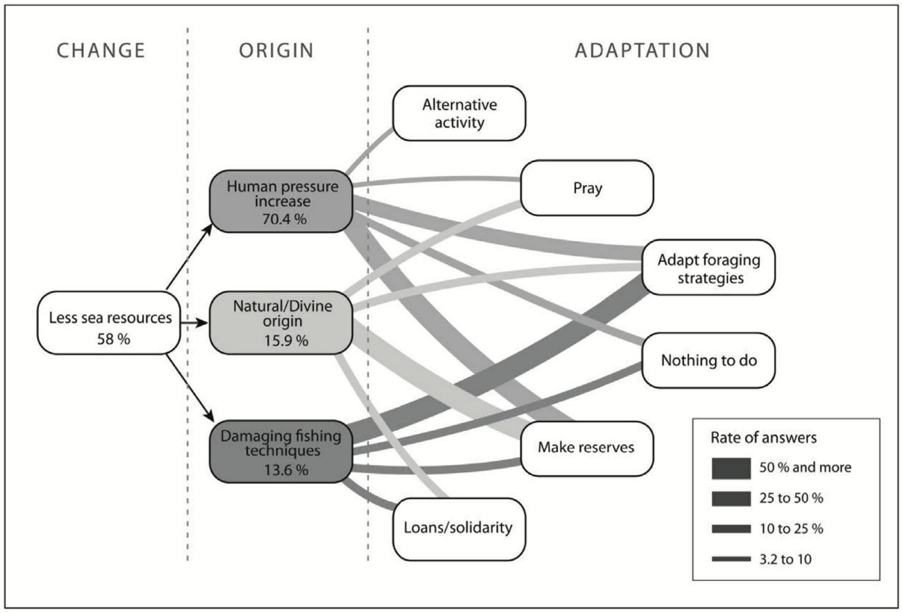

Fig. 4. Perceptions of change, causalities and adaptation mechanisms in Ambola for the sea environment and for the change the most quoted by respondents (n = 64).

destructive cyclone that struck Belitsake village, villagers migrated northwards to set up the Ambotsibotsike settlement. In Ambola, the rate of uneducated respondents was higher (24% of the respondents had no education against 4.3% for Ambotsibotsike). Formal western education has been showed in many studies to contribute to the erosion of traditional systems of knowledge and belief (Brosi et al., 2007; Fernández-Llamazares et al., 2015; Kai et al., 2014; McCarter and Gavin, 2014; Reyes-García et al., 2013; Voeks, 2010). Linked to the seemingly better knowledge of marine environments amongst Ambola residents is the number of household members who participate in pirogue-based fishing activities. On average, 1.08 members per household participated in pirogue-based fishing in Ambola compared to 0.91 in Ambotsibotsike. Although this score is offset by the higher number of gleaners per household in Ambotsibotsike, pirogue-based fishing is a spatially diverse activity which exposes participants to a multitude of possible fishing environments (as observed in their habitat classification in Fig. 1a). Gleaning, on the other hand, restricts participants within environmental boundaries (i.e. the inner reef and mangroves).

Respondents reported that most changes started 21–40 years ago. When respondents were asked to quote a period when a certain change occurred, they would very often pick round numbers to designate the year of start i.e. 2000, or the period range i.e. 20 years ago. This explains why 1996 is the most cited (the study took place in 2016). They identified the same period when describing NGO intervention, although WWF has actually been involved in the region for a shorter period (since 2008). In Ambotsibotsike, respondents identified the inland migration of the sand spit (included in the dune category) as being deleterious and causing the sedimentation of the mangrove channel and the

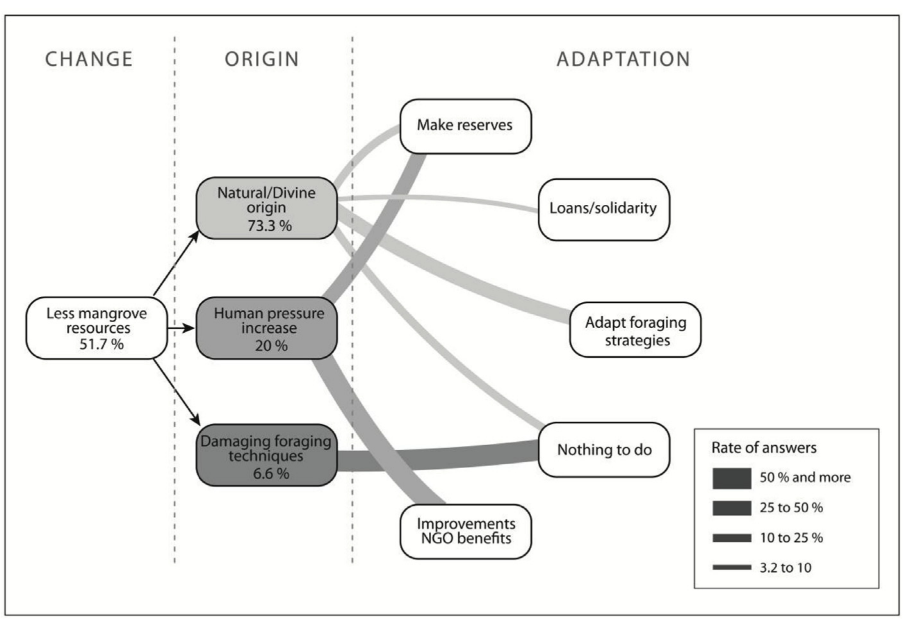

Fig. 5. Perceptions of change, causalities and adaptation mechanisms in Ambotsibotsike for the mangrove environment and for the change the most quoted by respondents (n = 29).

decrease in fish catches. Respondents identified the sand spit migration and sedimentation process as being at the origin of the reef's bad shape. In general, few respondents linked negative changes to a human origin. They rather found a natural, or divine origin to their observations. This causality is often evoked by traditional communities when coming to explaining some changes, rapid or not, observed in their environment (Apata et al., 2009; Gaillard et al., 2008; Vedwan and Rhoades, 2001). In Ambotsibotsike, where all respondents were found to be religious Christians (Table 2), this assessment stands to reason. Despite some studies show religiosity and beliefs in customary societies to have positive effects in the community e.g. increasing cooperativeness (Colding and Folke, 2001) many studies posit the eroding effect of Western religion on Traditional Ecological Knowledge (Caniago and Siebert, 1998; McCarter and Gavin, 2014; Tang and Tang, 2010; Turner and Turner, 2008). In Ambola, where some respondents claimed having no religion (8%), they reported a greater variety of vernacular names, linking the various processes or ecological elements more accurately, although the NGO interventions might have had an influence on these local perceptions.

Globally, respondents predominantly said the changes they observed to be impacting their livelihood, although they acknowledged it could result in a problem for the ecosystem itself for some categories. When coming to the shape of the substrate (coral reef cover namely), or the geomorphologic processes observed (sand migration, beach erosion), respondents mainly believed those changes to be an issue for the ecosystem itself. Yet, it is assumed that good coral reef health is fundamental in the recruitment process, ensuring shelter and a nursery role for many commercial species (Birkeland, 1997; Wilkinson, 2008). This truncated vision of the socio-ecosystem reveals the existence of a partial knowledge, lacking some systemic approach in the comprehension of the ecosystem and its interconnection with human wellbeing. The few positive changes observed by respondents of both villages were relative to the beach environment for Ambola and to the mangroves for Ambotsibotsike. In both cases, some NGOs have been taking action to implement environmental restoration programs, to enhance livelihoods and promote ecotourism.

Adaptation responses were quite revealing of the local conditions. In Ambotsibotsike, a significant portion of respondents (17.8%) said they were finding alternative activities to cope with the decrease in sea products. This response is facilitated by the village's close proximity to markets (the touristic district of Ifaty Northward and Toliara Southward), and the accessibility of these markets facilitated by a good road network. Ambotsibotsike residents have consequently been shown to allocate slightly more time to crop cultivation compared to their Ambolan counterparts, while their animal husbandry tends to lean more towards high value animals such as pigs and cattle, which are sold to the numerous restaurants around the area. This corresponding proportion was lower in Ambola, where the village's isolation, the poor road conditions (sandy off-roads) and the low accessibility to markets (the Onilahy river must be crossed using a ferry) contribute to limit the number of alternative activities available. It was found that Ambola villagers would rather adapt their fishing techniques i.e. fishing further in order to cope with decreasing catches, a finding that mirrors Aswani and Albert's case study on the Solomon islands (Aswani and Albert, 2015). In Ambola, making reserves appeared to be the preferred strategy to cope with the decrease in captured fish. This coping strategy reveals NGO interventions. The high rate of answers in both villages indicating that there is “nothing to do” in relation to adaptation is noteworthy. It is possible that the respondents feel hopeless and unsure about how they can adapt or that they believe that nothing can be done because it is in the hands of God and they feel powerless. Alternatively, it could also simply reflect respondents' fatigue as the adaptation question came last in the interview.

The comparison between Ambola and Ambotsibotsike provides insight into how external influences (markets, tourism, NGOs) do influence traditional knowledge and perceptions. The increased awareness of Ambola villagers compared to Ambotsibotsike about the human role in environmental change can be explained by the numerous NGO interventions and awareness programs in the region and also by the fact that residents of Ambola have lived there for much longer than those in Ambotsibotsike. Additionally, the village has been sampled numerous times to study the incidental captures of turtles (Walker and Roberts, 2005), their trade (Walker et al., 2004) or sea cucumber fisheries (McVean et al., 2005) which could have led to scientific knowledge inputs being incorporated into their knowledge system. In Ambotsibotsike, the settlement is younger and comprises inhabitants from diverse origins. The NGO interventions in the village are therefore also more recent compared to Ambola. Ambotsibotsike only had one NGO, the Honko project, an NGO seeking focused on promoting the sustainable use of the mangrove forests (http://www.honko.org/). This project's presence was reflected in positive answers among the respondents about the improved condition of the mangrove forests. In general, it appeared that the presence of NGOs could bias respondents' answers. Beyond the fact that interviewees, especially males, could have wanted to impress the interviewers by appearing knowledgeable (Case et al., 2005; Johns et al., 1990), they also behaved as if they had a duty towards the organization to report the positive effects that NGOs are supposed to generate.

In Ambola, the presence of the WWF and a nascent ecotourism market could help explain the locals' awareness of the role that humans play in contributing to climate change. Respondent's perceptions of human-driven change were more accurate. Many respondents could relate the absence or the decrease of sea products to a damaged reef environment. Some villagers explained the migration of fish to be due to the decrease of algae cover. Similarly, the bad condition of coral cover was attributed to damaging foraging techniques, the high fishing pressure or the increase of fishermen. Finally, a higher rate of positive changes was reported by Ambolan respondents compared to their Ambotsibotsike counterparts (e.g. a cleaner beach), again revealing the positive influence of NGOs and ecotourism. While most of the environmental linkages were correctly understood by respondents, some other perceptions were based on anecdotal conceptions, rooted in beliefs i.e. the absence of rain causing the decrease of algae cover or the absence of trees causing the lack of rain. Despite some studies reporting the deleterious effects of science on local knowledge (Johann, 2007), its integration, through NGOs can offer a broader appreciation of context beyond the local level and can contribute to local sustainability (Becker, 2003). In Ambotsibotsike, a location exposed to markets, respondents reported fewer belief-based anecdotes. The eroding role of markets on local knowledge and systems of beliefs is well known (e.g., Godoy et al., 1998; Reyes-garcía et al., 2005; Reyes-García et al., 2007; Gómez-Baggethun et al., 2013). Nevertheless, when most Ambolan respondents put forward the human responsibility in environmental changes, Ambotsibotsike residents allude to god's role. Beyond the primary explanation of religiosity, it is possible to postulate the hypothesis that the nearby presence of markets, together with the higher rate of livelihood diversification, contributes to diminish human pressure on the mangrove environment.

4.1. Management perspectives

In the context of climate change in developing countries, adaptation strategies are varied. These include the diversification of activities, exiting fisheries for a different source of livelihood or intensifying effort through investing in more resources (more fishers, improved gear, etc.) (Coulthard, 2009). To cope with decreasing catches, most respondents said they were going further off-shore to ensure a maximum return and a significant part said they were improving their gear and/or changing the fishing technique (e.g. spearfishing). In the South-West region of Madagascar, an increase in fishing effort was reflected by the larger number of fishers practicing (Le Manach et al., 2012). Small scale fisheries are of fundamental importance for food security in Madagascar

(72% of total catches in 2000s (Le Manach et al., 2012)), but are also supplying regional retailers for national and international markets (L 'haridon, 2006), hence increasing the demand. Finding alternative and/or diversifying activities is an option when the community is in close proximity to big towns or tourism centres. The range of options is reduced once the distance is increased and the accessibility is reduced. Similarly this configuration has implications for indigenous knowledge, the latter being more likely to be lost in communities that are closer to markets (Reyes-García et al., 2013).

In South-West Madagascar, the vital status of fisheries and the high vulnerability of the communities relying on them makes this region attractive to NGOs deploying sustainable fishing strategies in pilot villages. After Blue Ventures reported some cases of over-exploitation of fisheries in the most isolated areas of Madagascar (Harris, 2011), a wide-reaching campaign of marine conservation strategies has been launched by several NGOs and organizations, aiming at establishing sustainable fisheries. Few respondents alluded to solidarity strategies as a way to cope with decreasing fish stock, although collaboration between people was shown to improve adaptation processes (Abid et al., 2016). In the case of Ambola, the isolation, the beauty of the land and the presence of hotels makes ecotourism a viable prospect, even if the benefits of such ecotourism are debatable (Coria and Calfucura, 2012). Successful alternative income projects contributed, together with other factors, to ensure the success of community-based management strategies (Pollnac et al., 2001). NGOs have already had some success in this context, initiating ecotourism activity and teaching villagers how to maintain the beach cleanliness in Ambola, or teaching the importance of maintaining the mangrove forest in Ambotsibotsike.

In this case study, the empowerment of people appears to be the most viable strategy to ensure sustainable fishing practices, and to allow for the development of diversification options. Some authors assume that giving reliable access to climate change information and data will dissuade fatalistic approaches (Apata et al., 2009), and in so doing allow locals to benefit from science (Chaudhary and Bawa, 2011; Sharma and Shrestha, 2016). Sustainable options for the South-West Madagascar region are highly dependent on communities' capacity to diversify their livelihoods and on NGO involvement in some cases. In the case of Ambola where a marine reserve was supported by NGOs, the remoteness and the dryness of the area offer/s a limited range of options. Despite this, locals' higher awareness about environmental challenges, compared to Ambotsibotsike, provided the necessary conditions to ensure the effectiveness of community-based management models/bottom-up approaches. In contrast, Ambotsibotsike villagers have already seen their fishing activity decreasing and have started to diversify their livelihoods, favoured by the proximity of markets. Local people's accurate knowledge is a token of their environmental awareness and this understanding guarantees the acceptability of regulation or policies aimed at conversation (Thomassin et al., 2010).

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Appendix A

Table A.1
List of the cyclones which hit the south-west coast of Madagascar, with a (*) for events which trajectories meet at the Toliara area

Month-Year	Tropical cyclone	Highest level reached	Stade when over Madagascar	Within 100 km of Toliara
janv-71	Félicie	3	NA	*
janv-73	Hortense	3	NA	
déc-73	Esméralda	1	Tropical disturbance	*
févr-75	Héloïse	3	Tropical storm	
janv-77	Domitile	2	Tropical storm	*
févr-77	Hervéa	3	Tropical storm	*
déc-78	Angèle	3	Severe tropical storm	
févr-79	Dora	1	Moderate tropical storm	
janv-87	Hélyette	1	Sub-tropical depression	
mars-82	Justine	3	Severe tropical storm	*
janv-84	Caboto	1	Moderate tropical storm	
déc-85	Alifredy	1	Tropical depression	
mars-86	Honorinina	5	Intense tropical cyclone	
janv-88	Calidera	3	Tropical depression	*
janv-89	Calasanjy	3	Tropical depression	*
févr-89	Iana	2	Moderate tropical storm	
déc-89	Alibéra	5	Tropical cyclone	*
févr-91	Cynthia	3	Tropical cyclone	*
déc-91	Bryna	1	Tropical disturbance	
janv-93	Dessilia	2	Tropical depression	*
janv-94	Daisy	3	Tropical depression	*
févr-94	Geralda	5	Tropical depression	*
janv-97	Fabriola	2	Severe tropical storm	*
janv-97	Gretelle	4	Tropical depression	*
févr-98	Beltane	1	Tropical depression	*
janv-02	Cyprien	2	Tropical depression	*

(*continued on next page*)

Table A.1 (*continued*)

Month-Year	Tropical cyclone	Highest level reached	Stade when over Madagascar	Within 100 km of Toliara
janv-03	Fari	2	Moderate tropical storm	
févr-03	Japhet	4	Tropical disturbance	
mars-04	Gafilo	5	Severe tropical storm	
janv-05	Ernest	3	Tropical cyclone	*
janv-05	Felapi	1	Moderate tropical storm	*
janv-06	Boloetse	3	Tropical cyclone	*
déc-06	Bondo	5	Severe tropical storm	*
janv-08	Elnus	1	Tropical depression	
févr-08	Ivan	4	Intense tropical cyclone	*
janv-09	Fanele	4	Intense tropical cyclone	
mars-09	Izilda	2	Severe tropical storm	
mars-10	Hubert	2	Severe tropical storm	
mai-10	Joël		Sub-tropical depression	*
janv-12	Chanda	1	Tropical depression	
févr-12	Giovanna	4	Severe tropical storm	
févr-12	Irina	2	Moderate tropical storm	
févr-13	Haruna	3	Tropical cyclone	*
janv-14	Deliwe	1	Tropical disturbance	
févr-15	Fundi	2	Moderate tropical storm	*

Appendix B

Table B.2
General statistics on data collected using the questionnaires.

	Ambola	Ambotsibotsiky
Respondents characteristics		
Number of respondents	**25**	**23**
Percentage of males	76	60.9
16-35 Young	16.0	4.3
36-55 Mature	40.0	34.8
56 + Elder	20.0	21.7
Percentage of females	24	39.1
16-35 Young	4.0	8.7
36-55 Mature	20.0	21.7
56 + Elder	0	8.7
Mean Male age	39.3	46.5
Mean Female age	27.8	37.7
Employment rate (%)		
Rate of fishers as a first employment	56	52.2
Unemployed	4	26.1
Education (%)		
Secondary level education	24	30.4
Pre-primary & Primary level education	48	65.2
No Education	24	4.3
Ethnic group		
Vezo	18	20
Tanalana	4	3
Mahafaly	1	–
Betsileo	1	–
Tanosy	1	–
Religion (%)		
Catholic rate	84	47.8
Protestant rate	4	52.2
Others	4	0.0
None	8	0.0
Fishing activity		
Practice a fishing activity (in %)	84	95.7
Number of dimensions quoted (%)		

(*continued on next page*)

Table B.2 (*continued*)

	Ambola	Ambotsibotsiky
3 or less dimensions quoted	20	34.8
4 or 5 dimensions quoted	48	60.8
6 and more	32	4.3
Average number per respondent	4.24 (sd = 1.12)	3.86 (sd = 0.86)
Average number for sea environment	2.76 (sd = 0.96)	1.77 (sd = 0.61)
Free listing total score (ts)		
Beach	11	0
Dunes	5	4
Fore-reef	14	10
Land	15	19
Mangrove	0	**23**
Pelagic	18	8
Reefs	**23**	15
From cumulated answers	**n = 123**	**n = 108**
Changes observed		
Changes observed	104	85
Among which in Sea	*79*	*36*
Among which in Intertidal	*15*	*43*
Among which in Land	*10*	*6*
No change observed	18	21
NSP	*1*	*2*
Type of change categories (%)		
Less resources	54.8	64.7
Substrate change	14.4	4.7
Improvements	17.3	1.2
Size decrease	8.6	8.2
Geomorphologic origin	4.8	16.5
Adaptation strategies (for negative changes)		
Alternative activity	3.1	17.8
Adapt foraging techniques	19.4	31.5
Make reserves	24.5	5.5
Pray	7.1	0.0
Debts/loans	2.0	2.7
Nothing to do	41.8	37.0
Don't know	2.0	5.5

Appendix C

The free listing exercise consisted in asking respondents about the way they segment their environment through asking the question “what are the different dimensions in your environment”. Some respondent would have a very simple classification of their environment (sea, land and beach) while others would list a wider range of environmental units and places. Interviewers listed each environmental unit in the order that they were identified. In some instances, respondents and translators were drew together to make sure the respondent was well understood (Fig. C.1).

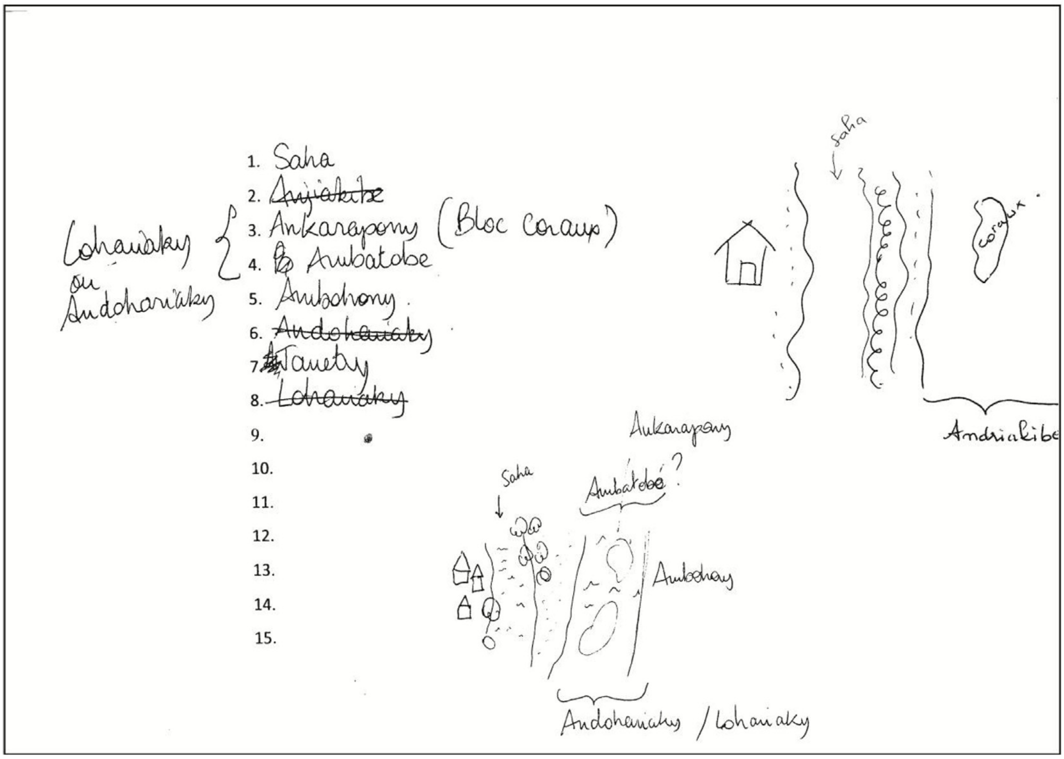

Fig. C.1. An extract of the questionnaire for the free listing exercise.1

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